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Control of Railway Operation on Open Access Networks

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Abstract

One of the key elements of the reformation of European railways is the introduction of open access. Current discussions on that topic concentrate almost entirely on economic and financial issues of open access. But the introduction of open access will also have a significant effect on the way the operation of a railway is being planned and controlled. Following the directives of the EU legislatures, the introduction of open access was combined with separating two types of railway companies—infrastructure operators and train operating companies. The product that is sold by the infrastructure operator and bought by the train operating companies is the so-called train path. This principle has a great influence on scheduling, which is in charge of the infrastructure operator. In the scheduling process, the task of the infrastructure operator is the detailed calculation and allocation of train paths in accordance with the orders of the train operating companies. This requires advanced computer-based scheduling systems that can calculate the train paths in the so-called blocking time model. When conflicts between the train paths of different train operating companies are found, a solution has to be developed. In a running operation, dispatchers may alter the timetable to keep the traffic running. However, they have to do this with respect to the operational needs of the train operating companies. This requires powerful information systems to exchange traffic data between the control centres of the infrastructure operator and the train operating companies.

Keywords: Railway operation, Scheduling, Open access, Control centres

1 Characteristic Features of European Railway Operation

1.1 Operating Principles

For a discussion of the open access problem and especially the effect open access has on planning and control of railway operation, a basic understanding of some essential characteristics of European railway operation is necessary. Passenger operation is the backbone of the European railway system. About 75%—80% of all train kilometres is passenger traffic. Since during daylight hours most capacity is consumed by passenger traffic, freight traffic is concentrated during night hours when the density of freight on mainlines can be extremely high. This requires high-performance classification yards. It is no wonder that the world's second largest classification yard is Maschen Yard near Hamburg, Germany, with 112 classification tracks. All train operations are entirely scheduled, passenger trains often with clockface schedules. Scheduling is an essential feature of European railroads. This does not necessarily mean that all traffic is planned a long time in advance, but rather that every train must have a predetermined train path that does not have any conflicts with other trains. Traffic management at the control centre level involves allowing the traffic operating as planned to continue doing so while attention is directed to the exceptions.

The basic document of traffic planning and control is the time-distance traffic diagram of the stringline style. All mainline operation is entirely signal-controlled, even on lines with old signalling technology. Track warrants are only used on a very few branches. Signal-controlled fixed block operation has been the standard form of operation since the 1870s.

1.2 Types of Railway Companies

Following the directives of the EU legislatures, the introduction of open access was combined with separating two types of railway companies—infrastructure operators and train operating companies. Both kinds of railway companies may be combined in a holding company if the corporate independence of the infrastructure operator is guaranteed within the holding. The infrastructure operators are in charge of the maintenance of the right of way, train dispatching, and train scheduling on their lines. The train operating companies are in charge of the maintenance of rolling stock, train driving, and scheduling and dispatching of crews and equipment within their own train system.

In an open access railway system there is a commercial connection between the infrastructure operator and the train operating companies. Since a market between these types of railway companies never existed before, the question is what merchandise is to be sold on that market. On European railways, the product that is sold by the infrastructure operator and bought by the train operating company is the so-called train path. A train path describes the usage of the infrastructure for a train movement in track and time. It is more than just a schedule, a trains path also contains the right to run a train on a route under specified conditions. Every train operator who wants to run a train has to buy a train path on a cost per train-kilometre basis (Schwalbach, 1998). This principle has a great influence on the scheduling process described in section 2.

2 Open Access in the Scheduling Process

2.1 Allocation of Train Paths

Scheduling railway traffic has two different aspects:

- network scheduling,
- train scheduling.

Network scheduling means to build a network of transportation routes with sufficient connections in freight and passenger terminals and to organise asset circulation (equipment and staff) on that network. Train scheduling means the detailed calculation and allocation of the train paths of all trains that run over the same line. In an open access system, network scheduling is done by the train operating companies while train scheduling is done by the infrastructure operator.

The scheduling process is done in two steps: At first, the network scheduling for the different train systems is prepared by the train operating companies. The train operating companies plan the routes their trains should run through the network, the times they would like to run the trains, and connections between different train routes. A train operating company does the network scheduling only for its own train system without talking to competing train operators. As a result, there may be many conflicts among the train paths proposed by the various operating companies. At this stage of planning, these conflicts are not yet to be seen.

After finishing the network scheduling, the train operating companies have to order train paths from the infrastructure operator. Now, the infrastructure operator starts the train scheduling on its lines, i.e. the detailed calculation and allocation of train paths in accordance with the orders of the train operating companies (the so-called “train path management”). When conflicts between the train paths of different train operating companies are found, the infrastructure operator will work out a solution and try to get an agreement from the concerned train operating companies. If no agreement is found, the train paths will be awarded to the highest bidder. When the timetable is complete, the infrastructure operator will produce all operational documents and will supply the train operating companies with the working timetables for their train crews.

From the viewpoint of scheduling, there is a distinction between regular trains and extra trains. Regular trains are all trains that have a schedule in the yearly timetable. Train paths for regular trains have to be ordered several months before the yearly timetable comes into effect. All train operating companies that order their train paths the required time in advance must be treated by the infrastructure operator without discrimination. Today, almost all passenger trains are regular trains. Extra trains are trains that have no schedule in the yearly timetable. But this does not mean that these trains are non-scheduled trains, since a train path is required for every train. So far, usage of the term extra train differs from the practice in North America and some other countries. Train paths for extra trains can be ordered at any time. E.g., in Germany, the biggest network operator DB Netz allows train operators to order a train path just a few hours before departure. It is not always guaranteed that a clear path will be found for a train at the desired departure time, however. Both regular and extra train paths must not have any schedule conflicts. Today, an increasing share of freight traffic is running as extra trains.

This requires a very high flexibility in scheduling that can only be done by advanced computer-based scheduling systems.

2.2 Requirements to Scheduling Systems

In open access operation on lines with a high density of traffic, train scheduling can no longer be done by the old manual scheduling methods. Appropriate open access management requires powerful computer-based scheduling systems that can quickly calculate a train path and precisely recognise all scheduling conflicts with other train paths. An essential feature of such a scheduling system is a precise calculation of how the infrastructure for a train movement is used in track and time. For that purpose it is not sufficient to describe a train path just by its stringline graph. There must also be a model to describe the "time channel" a train movement produces around its time-distance line. A model that describes that time channel very exactly is the so-called blocking time model. The same principle is also well known in analytic models for capacity management (Pachl and White, 2003; Pachl, 2004). The idea of the blocking time model was developed in the late 1950s by *O. Happel*, who was at the time the chief scheduling officer in the Frankfurt headquarters of German Federal Railways (Deutsche Bundesbahn) (Happel, 1959). Implementation of that idea in practical railroad scheduling had to wait several decades until computer-based scheduling systems became available, however. Use in daily operation required yet more time and computer system development. The German infrastructure operator DB Netz introduced a computer-based scheduling systems based on the blocking time model in 1998 (Brünger, 2000). Beside the German scheduling system, the blocking time model is also used in scheduling systems of other European railways, e.g. in the United Kingdom (Stallybrass, 2005).

The blocking time is the total elapsed time a section of track (e.g. a block section, an interlocked route) is exclusively allocated to a train movement and therefore blocked for other trains. Therefore, the blocking time of a track section begins with issuing a train its movement authority for this section (e.g. by clearing a signal). The movement authority must be issued before the train has reached the braking distance in approach to this section. For example, in signalled operation the train must not yet have passed the signal that gives the approach indication to the signal at the entrance of the section. The blocking time ends after the train has completely left the section and all signalling appliances have been reset to normal position so that movement authority could be issued to another train to enter the same section. Thus the blocking time of a track section is usually much longer than the time the train occupies the section. In a territory with line-side signals the blocking time of a block section consists of the following time intervals:

- the time for clearing the signal
- a certain time for the train driver to view the clear aspect at the signal that gives the approach indication to the signal at the entrance of the block section (this can be a block signal or a separate distant signal)
- the approach time between the signal that provides the approach indication and the signal at the entrance of the block section
- the time between the block signals

- the clearing time to clear the block section and—if required—the overlap with the full length of the train
- the release time to “unlock” the block system

Figure 1 shows the components of the blocking time of a block section without a scheduled stop. If the train had a scheduled stop at the signal at the entrance of the block section, the approach time would disappear.

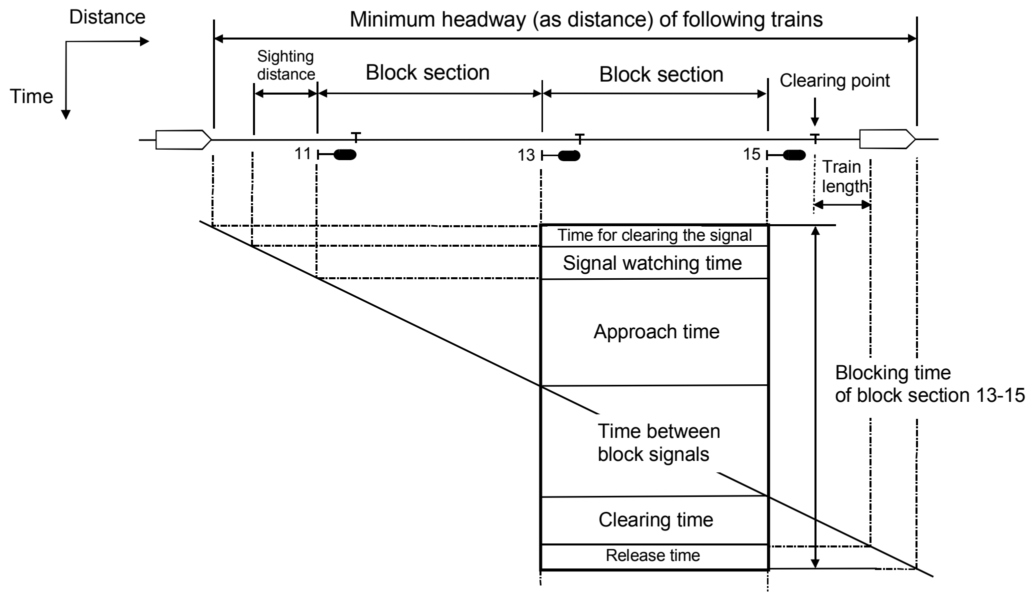

Figure 1: Blocking time of a block section for a train without a scheduled stop

In a territory with cab signalling, the principle is quite similar but the approach time is now the time the train runs through the braking distance that is signalled by the cab signal system. Drawing the blocking times of all block sections a train occupies into a time-over-distance diagram leads to the so-called “blocking time stairway“ (Figure 2). The blocking time stairway represents perfectly the operational use of a line by a train.

When applied to scheduling, the basic rule is that the blocking times of two trains must never overlap. In the German standard scheduling system, the scheduling is done on a screen that shows a stringline diagram of the line. For every train a train path is calculated with running times in accordance to the characteristics of the train (e.g. weight, length, tractive effort and braking characteristics) and of the line. For a precise detection of scheduling conflicts, the blocking time stairways are displayed for each train path (Figure 3). In case of overlapping blocking times, the scheduling operator has to solve the conflict by postponing or modifying the train paths or by changing the train sequence. Between the blocking time stairways of two trains must always be a minimum buffer time to avoid the transmission of small delays from one train to another. The finished timetable is then printed as a stringline traffic diagram without blocking time stairways. As the basic document of traffic control, this diagram is also being fed into the dispatching system in an electronic format. All other schedules and timetable documents are produced from the data of these traffic diagrams. For a more detailed description of the blocking time model see (Pachl, 2002).

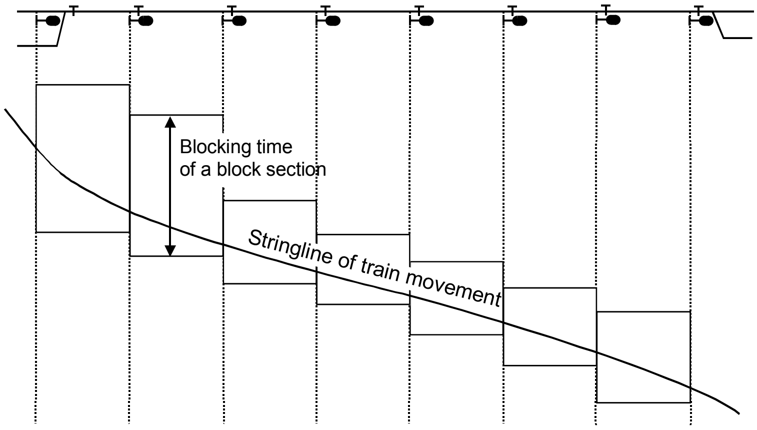

Figure 2: Blocking time stairway

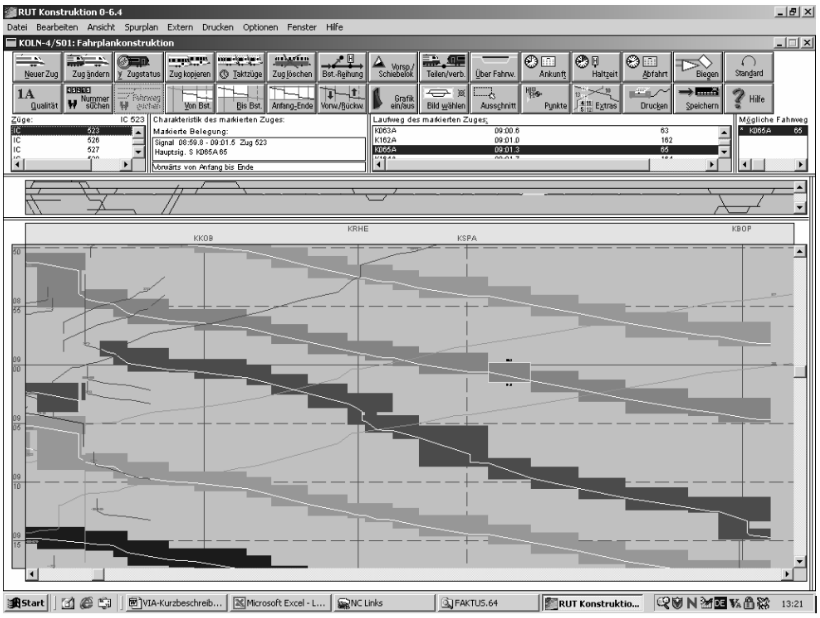

Figure 3: Screenshot of the standard DB scheduling system with blocking time display

2.3 Current Discussions

As mentioned above, trains paths for extra trains can be ordered at any time. To meet the needs of the shippers, an increasing share of freight trains runs as extra trains. The train paths for many freight trains are ordered a very short time in advance, sometimes just a few hours. This way, freight train scheduling differs completely from passenger train scheduling. As a result of that development, the yearly timetable contains only a part of the real traffic, mainly passenger trains and freight trains that run on a regular basis. Thus, when establishing the yearly timetable, a lot of traffic is not yet known. Trains paths for freight trains ordered a very short time in advance do often not even appear in the scheduling systems. The train dispatcher of the network operator will use his computer-based dispatching system to establish conflict-free train paths for these trains. The infrastructure operator has now the serious problem how to ensure scheduling quality in the yearly timetable. Even the smartest computer-based scheduling system with detailed blocking time calculations will not help much if a significant part of the traffic does not appear on the screen. There are several concepts of how to solve this problem. Typical ideas are:

- Enforced freight train scheduling by filling up the yearly timetable with pre-constructed train paths for freight trains,
- Reserving clear time windows in the yearly timetable that can be filled with train paths for extra trains on a flexible basis.

However, the perfect solution has not yet been found. This problem is still an important topic of research.

3 Dispatching of Open Access Movements

3.1 Types of Control Centres

Since the train operating companies are separated from the infrastructure operator, the dispatching of crews and equipment is also separated from train dispatching. For this purpose, both types of railway companies have their own control centres. Train dispatching is done in the operation control centres of the infrastructure operator. Today, all mainlines are equipped with a computer-based dispatching system that works in some way similar to the scheduling system. Every time a train enters a block section, it is automatically detected by the train describing system and transmitted to the control centre. From this data, an electronic stringline diagram with time-distance graphs is displayed on the dispatcher's screen (Figure 4). So, the dispatcher can easily compare the real traffic of a line with the scheduled traffic (Breu et. al., 2003; Barke et al., 2005). Figure 5 shows the structure of a typical operation control centre.

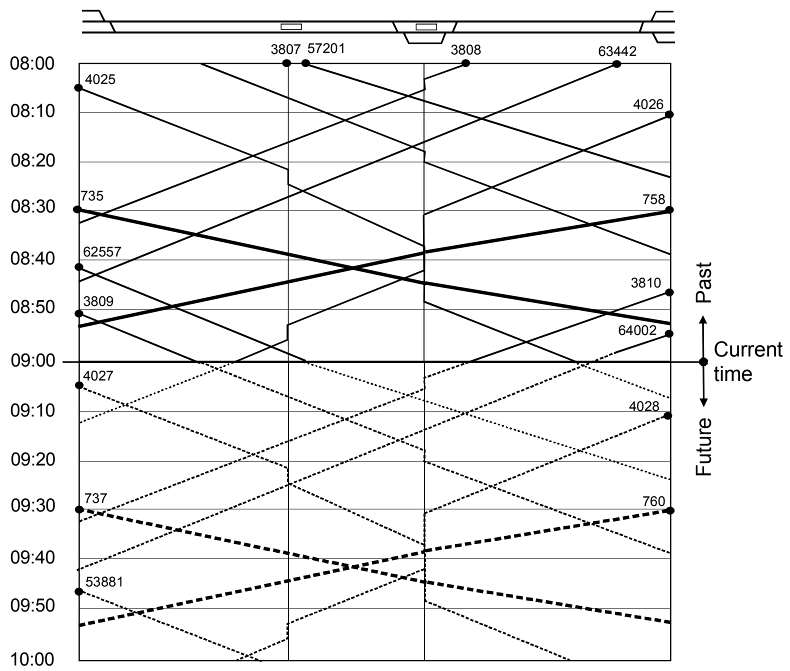

Figure 4: Principle of an electronic stringline diagram with online information for train dispatching

Beneath the operation control centres of the network operator, the train operating companies run their own transportation control centres to supervise their trains and to manage equipment and crew circulation. The operation control centres of the network operator supply the transportation control centres of the train operating companies with current location data of their trains. The train operating companies get a reasonable forecast of when their trains will reach terminals, important stations, or their final destinations. However, a train operating company will never see any train locations of competing companies. Instead of obtaining train location data from the infrastructure operator, some train operating companies have installed their own train location systems. Common solutions are GPS-installations on locomotives or the use of portable radio-based communication devices which enable the train driver or conductor to send Short Message Service (SMS) messages with a delay code at specified stations. In the transportation control centre, the dispatcher has a screen with a traffic diagram in which the time-distance graphs are automatically postponed in response to the received delay codes. These methods can provide accurate current information, but the most accurate arrival projections can only be made by the people controlling the traffic.

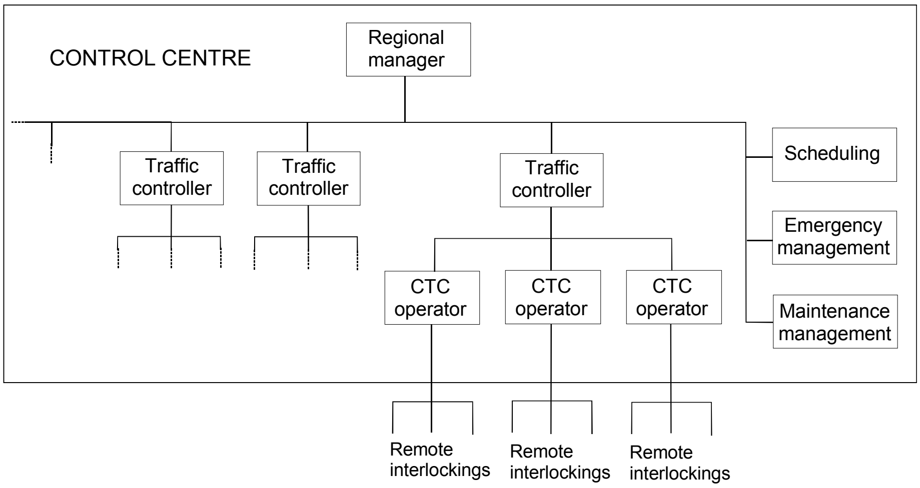

Figure 5: Typical structure of an operation control centre

When a train is so delayed that it would miss a scheduled connection where passengers or equipment should change to a train of another line, the train dispatcher of the operation control centre will inform the transportation control centre of the concerned train operating company about the conflict. The dispatcher of the train operating company may request to keep the connection regardless of the delay. But this is only a request, the final decision is always in charge of the train dispatcher under consideration of the operational situation in the network. If the train dispatcher decides to reject the request of the train operating company, this decision will be final. This principle ensures that there is always only one “authority person” that is responsible for train control in the network, eliminating the problems of indecision or continual change of decision, and the generally resulting chaos. In Germany, the communication between the operation control centres and the transportation control centres of train operating companies that belong to the DB holding company, is made by an IT system without need for time consuming telephone communication. The computer-based train dispatching system will automatically detect conflicts at scheduled train connections and transmit an electronic message to the transportation control centre. The request of the dispatcher in the transportation control centre to keep a connection, and the final decision of the dispatcher in the operation control centre are done by short entries in a mask on the computer screen. The dispatcher in the operation control centre has a screen that shows a sheet with all connections which might get lost. It includes a column in which the connections that are requested to be kept are shown. The dispatcher can see if a connection is requested to be kept and he can directly enter his final decision.

However, that highly developed dispatching system was only possible because the network operator DB Netz and the biggest train operating companies are still part of the DB holding company. In Germany, DB's passenger operator DB Fernverkehr is the only train operating company that runs a nationwide long distance passenger system. To make dispatching easier, the operation control centres of DB Netz and the transportation control centres of DB Fernverkehr use the same control districts. Today, within the DB network, train dispatchers and transportation dispatchers even work in the same buildings. A separation of the German infrastructure operator from the DB holding and the occurrence of additional operators of long distance passenger services will make the situation much more complicate.

3.2 Requirements to Train Dispatching Technologies

In the last decades, the most important development in train dispatching technologies was the integration of vital interlocking systems and non-vital control systems as train describers and automatic route setting systems. The current development is the integration of dispatching and scheduling systems. The most obvious part of that development is the introduction of timetable-based automatic route setting systems. The interlockings are automatically controlled by timetable data that is produced by the dispatching system. The work of a train dispatcher looks more and more like the work of a scheduling officer. The main difference is the planning period. The train dispatcher both modifies the given timetable to manage delay in the running operation and establishes schedules for extra trains. For these tasks the dispatching system must have scheduling capabilities at a similar level as pure scheduling workstations. The latest dispatching systems used in the German operation control centres have already an integrated blocking time calculation and display for establishing train paths for extra trains. However, most dispatching systems do not yet have these capabilities. There is still a significant demand for research.

4 Conclusions

The introduction of open access has significant influence on the way railway traffic is planned and controlled. Every train operator who wants to run a train has to order a train path from the infrastructure operator. In the scheduling process, the task of the infrastructure operator is the detailed calculation and allocation of train paths in accordance with the orders of the train operating companies. This requires an advanced computer-based scheduling system that is much more powerful than traditional scheduling methods. An essential requirement is to calculate and display train paths in the so-called blocking time model which can exactly detect all scheduling conflicts. In a running operation, traffic regulators and dispatchers may alter the timetable to make up delays and to keep the traffic running. Since an increasing share of freight trains run on train paths that are not planned in the yearly timetable but ordered a very short time in advance, the train dispatchers have also to establish schedules for these trains. For these reasons advanced dispatching systems for open access operation must have scheduling capabilities very similar to real scheduling systems.

Another problem of open access management is the communication between the operation control centres of the infrastructure operators and the transportation control centres of the train operating companies. Although train dispatching is in charge of the infrastructure operator, dispatching decisions that have significant influence on the internal procedures of train operating companies (e.g. lost train connections) should be discussed with the concerned train operators. This makes the control of operation more complicate and requires powerful information systems to exchange traffic data between the control centres of the infrastructure operator and the train operating companies.

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